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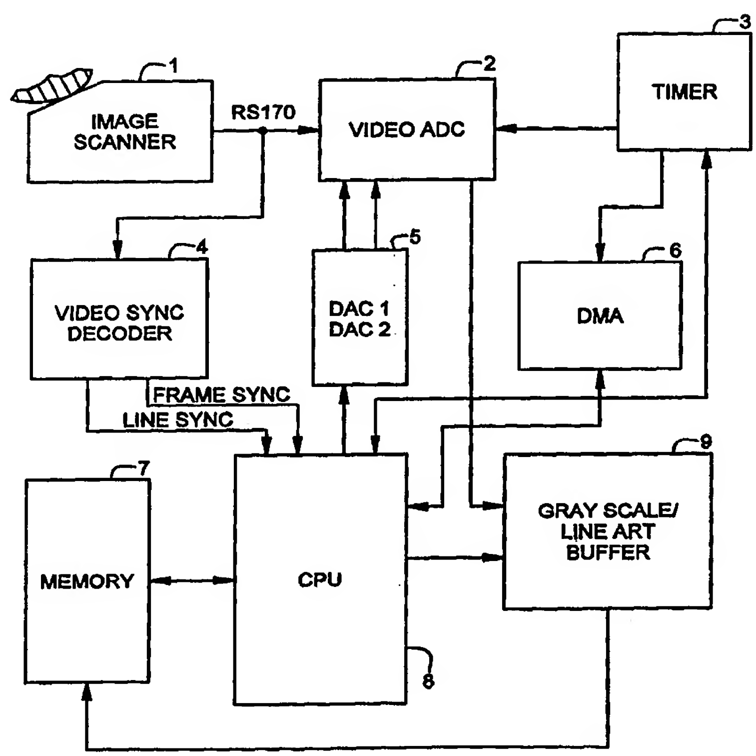
(54) Title: INEXPENSIVE ADAPTIVE FINGERPRINT IMAGE ACQUISITION FRAMEGRABBER

(57) Abstract

The adaptive framegrabber automatically estimates the dynamic range of the acquired image and sets up a proper offset and measurement range for the video analog to digital converter (ADC). It could also be operated in two different modes, in one the image is acquired as a full grey scale image, and in the other – as a line art (black and white) image. Full controls over the image size and resolution are obtained through the provision of a programmable timer and CPU.



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INEXPENSIVE ADAPTIVE FINGERPRINT IMAGE ACQUISITION FRAMEGRABBER

BACKGROUND OF THE INVENTION

The majority of contemporary fingerprint identification and verification systems are personal computer based and use standard general purpose video frame grabbers to acquire images from fingerprint image scanner devices. Those video frame grabbers are designed to acquire video signals from various types of video sources. Changes to acquisition parameters are done manually through a video grabber software manager. This, however, does not allow the automation of some particular operations essential for proper acquisition of fingerprint images, like the automatic adjustment of the offset and measurement range of the video analog to digital converter to compensate for the differences between acquired images and also the automatic finger placed detection. The whole acquired image is usually digitized and saved in memory, even though only part of it may be necessary for the particular application. Also the acquired frames are always saved in memory as grey scale images, and if the application requires a line art (black and white) image, it has to be converted additionally, which wastes computer time, especially in case of real time applications. Also, there is usually not much control over which and how many frames to skip and respectively acquire.

SUMMARY OF THE INVENTION

A highly integrated adaptive framegrabber for fingerprint image acquisition is described.

The framegrabber can be easily adjusted to acquire each frame from, for

example, an input RS170 compliant video signal, or to acquire each second, each third etc. frames.

The size of the image to be actually acquired from each frame is adjustable by means for defining how many lines to be skipped at the beginning of the frame, how many lines to be acquired; then how many pixels to be skipped at the beginning of each line and how many pixels are to be acquired from each line. The size of the acquired pixels is also controllable.

The framegrabber has two software controllable modes of operation: (a) full grey scale, where the pixel depth is defined by the size of the output data word from the video ADC, and (b) line art, where the pixel depth is just one bit (black and white).

At the beginning of the acquisition cycle, the framegrabber is always in a grey scale mode of operation. A window of pixels is extracted from the first acquired frame. An average vector is calculated from this window. This vector is used for two different purposes when the framegrabber is used for fingerprint image acquisition.

The first purpose is to detect if a finger has been placed on the fingerprint scanner device. This is done by comparing the calculated vector to a predefined threshold. If the result of such a comparison is negative, a next frame is acquired, a window is extracted, and an average vector is calculated. This operation repeats until a positive comparison is detected or the system times out.

The second purpose for which the average vector is calculated is to help select proper offset and measurement range for the video analog to digital converter (ADC). This is done by using the last calculated average vector to select optimum values for the offset and measurement range of the

video ADC and downloading them to a dual digital to analog converter (DAC), providing necessary references for the video ADC. Thus the dynamic range of the video ADC always matches the dynamic range of the acquired image.

After the optimum range and offset have been adjusted, the framegrabber can be either left to acquire next images in full grey scale mode of operation, or switched to a line art mode of acquisition. In this last case, next frames to be acquired will be automatically transformed into line art images and saved in the memory having pixels containing only two values, hexadecimal numbers 00 or FF (in case of 8-bit video ADC data bus).

An embodiment of the adaptive framegrabber for fingerprint image acquisition, according to aspects of the present invention, includes a central processing unit (CPU), which controls and synchronizes the operation of all parts comprising the adaptive framegrabber, a memory to save acquired frames, a video analog to digital converter (ADC) with controllable measurement range and offset, or top and bottom of the range; a dual digital to analog converter (DAC) to provide necessary references for the video ADC , a timer to define the conversion cycle of the video ADC, and also to cause periodic direct memory access (DMA) requests, a direct memory access controller (DMA) to read data from the digital outputs of the video ADC and save it in predefined successive addresses in the memory; a video synchronization pulses decoder, extracting frame and line synchronization pulses from an input RS170 compliant video signal, and a CPU controlled grey scale/line art buffer, transparent to the input data stream when in grey scale mode of operation, and transforming, on the fly, the input grey scale data stream into line art output data stream.

In the preferred embodiment, the CPU, the DMA controller, and the timer are integrated into one multifunctional block, but any other

combinations are possible, depending on a particular application.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a full block diagram of the specialized adaptive framegrabber for fingerprint image acquisition.

Fig. 2 shows an implementation of the grey scale/ line art buffer.

Fig. 3 shows an example of acquired video frame, with the window used to calculate the average vector inside.

Fig. 4a shows the signal of a single tv line with no finger placed on the fingerprint image scanner. Fig.4b shows the signal of a single tv line with relatively poor (pale) fingerprint image, and Fig.4c shows a single tv line with a very good (high contrast) fingerprint image.

Fig.5a is a flowchart describing the operation of the adaptive framegrabber during execution of the fingerprint enrollment algorithm.

Fig.6 is a flowchart describing the sequential operations of the adaptive framegrabber during verification algorithm execution.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig.1 shows the overall structure of a specialized adaptive framegrabber for fingerprint image acquisition according to aspects of the invention. The preferred implementation is based on Motorola's DSP56303 digital signal processor, which incorporates on a single chip the central processing unit (CPU) 8, the direct memory access controller 6, and the timer 3; the Microlinear video analog to digital converter (ADC) 2 ML6401 and dual digital to analog converter ML2330 5, but any other implementation based

on different type of suitable components is possible.

A RS170 compliant video signal comes out of the fingerprint scanner device 1 (or other source of video signal if the application is different) and is applied to the input of the video ADC 2 and the video synchronization decoder 4 simultaneously.

The timer 3 is initialized for pulse width mode of operation, its output is enabled and connected to the "start conversion" input of the video ADC 2.

The direct memory access controller (DMA) 6 is initialized for single word transfer on request mode of operation and timer 3 is the source of this request.

When the framegrabber is enabled, the signal from the frame line synchronization output of the video synchronization decoder 4, connected to one of the external interrupts lines of the CPU 8 is enabled and causes a CPU 8 vectored interrupt.

The CPU 8, after receiving the frame interrupt from the output of the video synchronisation decoder 4, checks with a preset counter "frames to skip", which in this case is a software based one, and if it is not zero skips the current frame and subtracts one from the counter. When the counter value reaches zero and the frame is to be acquired, the CPU 8 enables the interrupts from the line synchronization output of the synchronisation decoder 4, and this second line is also connected to another external interrupts line of the CPU 8. The CPU also recovers the preset value for frames to skip in the "frames to skip" counter. After that, at each line interrupt the CPU 8 checks a special preset counter "lines to skip" for zero and if it is different, it subtracts one from the counter and does not acquire this line. This cycle repeats until the "lines to skip" counter has

value zero. The next line synchronization interrupt causes following actions from the CPU 8. It starts checking a preset "lines to acquire" counter for zero at each consecutive line synchronization interrupt. The timer 3 is also enabled after each consecutive interrupt the CPU 8 loads into timer compare register of the timer 3 a digit defining the number of pixels to be skipped (not acquired) at the beginning of the current line. When a comparison occurs, the CPU 8 enables the DMA 6 and the acquisition of pixels from the current line begins. The number of pixels to be acquired is predefined during initialization of the DMA 6, so, when this number is reached, DMA 6 disables itself. All counters mentioned in this description are software ones illustratively, but they could be of any kind in other implementations. The DMA controller 6 reads the pixel values from the output of the video ADC 2 and saves them into consecutive addresses in memory 7.

A special block named grey scale/line art buffer 9 is connected on the bus between the output of the video ADC 2 and the memory 7. Its functionality will be described later, when Fig.2 is explained.

The timer 3 defines the width of the pixels by controlling the timing between conversion cycles of the video ADC 2, and also requests to the DMA controller 6.

The cycle for consecutive line acquisition repeats itself until the counter "lines to acquire" is at zero.

This will mean that the portion of the frame to be acquired has been successfully acquired by the frame grabber. Line synchronization interrupts are disabled, and process repeats itself. After next frame synchronization interrupt the CPU 8 checks if the frame has to be acquired and so on until the framegrabber is disabled.

The "frame to skip" , "lines to skip" and "lines to acquire" counters are initialized after a frame has been acquired.

This type of organization of the framegrabber allows easy automatic adaptation to various video standards for black and white video (EIA, CCIR) and also most economical memory utilization. Only useful part of the frame is saved in the memory 7. The option to skip several frames, before acquiring a next one, allows a very convenient option for real time processing in pauses between acquired frames, and easy variation in the length of those pauses.

Fig. 2 shows the preferred embodiment of the grey scale/line art buffer 9. This functional block is placed between the digital outputs of the video ADC 2 and the memory 7.

Its main building block is the two inputs to one output multiplexer 12, with data word length equal to the width of the bus between the video ADC 2 and the memory 7. The multiplexer has a mode select input controlled by the CPU 8. When this input is in state corresponding to grey scale mode of operation, the multiplexer 12 inputs A0..A7 are directly connected to its outputs D0..D7 and digital data saved into the memory 7 is exactly the data from the outputs of the video ADC 2.

When, however, the mode select input is in state to enable the line art (black and white) mode of operation, the multiplexer 12 inputs B0..B7 are connected to corresponding outputs D0..D7. In this case, as it could be seen, following boolean equation representing functional blocks "or" 10 and "and" 11, if digital data word at the outputs of the video ADC 2 has a hexadecimal value less then hexadecimal 90, then all B0..B7 inputs and their corresponding outputs D0..D7 of the multiplexer 12 will be forced to zero, thus a hexadecimal digit 00 will be stored in memory 7. If, however, the digital data word at the output of the video ADC 2 is greater or equal

to the hexadecimal number 90, then all B0..B7 inputs and respectively D0..D7 outputs of the multiplexer 12 will be forced to one, and the word to be saved in the memory 7 will have a hexadecimal value FF.

This way, the grey scale/line art buffer 9 allows some or all of the acquired as grey scale images, and some or all of the frames to be acquired as line art images. The digital threshold of the grey scale/line art buffer 9 could be set to any other number different from the selected hexadecimal value 90.

Fig. 3 illustrates one of the ways to define a vector window 14 within acquired image 13. As it could be seen in this case, the image 3 has a size of 160x160 pixels and the vector window 14 occupies the middle part of this image with a size of 64x64 pixels. The average vector of the vector window 14 is calculated by adding the values of all pixels comprising this window and dividing their sum by the number of pixels comprising the vector window 14.

The average vector, calculated this way, is used for some adjustments, which will be described when enrollment and verification flowcharts for the framegrabber, shown on Fig.5 and Fig. 6 respectively are described.

Fig. 6 shows the flowchart of the adaptive framegrabber during fingerprint verification process. After a command for the start of the fingerprint verification processes has been issued by the CPU 8, the adaptive framegrabber is enabled and switched into grey scale mode of operation 23. After the first frame has been acquired (it is possible also to acquire only an image of the size of the vector window), the vector window is extracted and the average vector calculated 24. Then the average vector is compared against a preset threshold value to determine if a finger for verification has been placed 25 on the fingerprint image scanner 1. If the comparison fails, the same process repeats with the next frame - the

average vector is calculated 24 and again compared against the threshold 25, and so on until a positive result from comparison is detected, or the system times out. After the positive result of the comparison, the value of the last average vector calculated 24 is used to select from a look up table values 26 for the best offset and measurement range of the video ADC 2. Another way to select best offset and measurement range of the video ADC is to compare the average vector to a number of thresholds each corresponding to predetermined values for the offset and measurement range of the video ADC and select the closest one. The values for the best offset and measurement range are then downloaded by the CPU 8 to analog to digital converters (DAC1/DAC2) 5, which outputs are connected to corresponding inputs of the video ADC. After this operation is completed, the adaptive framegrabber is switched into line art mode of acquisition 28, if the verification algorithm requires such mode for its operation, and starts acquiring frames from the fingerprint image scanner to be processed according to particular requirements of the chosen fingerprint verification algorithm. It is worth noting that the flowchart shown on Fig.6 is quite suitable also for implementation with other image verification applications like face, iris, eye, etc.

Fig.4 helps to illustrate how the calculated average vector is used for "finger placed" detection and also for proper adjustment of the offset and measurement range of the video ADC 2. Fig. 4a shows a video line signal corresponding to "no finger placed" on the fingerprint image scanner 1. The average vector calculated from a window comprised of this type of lines will have maximum value. Fig.4b shows a video line signal corresponding to a poor (pale) fingerprint image, and Fig.4c shows a video line signal corresponding to a sharp (high contrast) fingerprint image. The average vector from the window corresponding to the signal on Fig.4b will be smaller than that from Fig.4a but greater than the one calculated from a window corresponding to the signal from Fig.4c.

If a threshold is defined, lower than the one corresponding to Fig.4a, but greater than the average vector corresponding to Fig.4b, a "finger placed" detection will be easily and reliably realized.

At the same time in order to get similar quality digitized images from line signals shown on Fig.4b and Fig.4c, the measurement range and offset of the video ADC 2 should be adjusted on the basis of the average vectors values that the average vector from Fig.4b will require greater value for the offset and smaller measurement range. This way, the dynamic range of the video ADC 2 will fit more closely to the input signal, and acquired images in both cases will be much closer in quality than the input signals, shown on Fig.4b and Fig.4c.

In order to adjust the ADC 2 offset and measurement range as close as possible to the currently acquired fingerprint image, the process of calculation of the average vector and consecutive corrections to the offset and measurement range of the ADC 2, could be done iteratively, until for example the value of the average vector is brought within a certain predefined threshold window. Thus, the input fingerprint images will be greatly normalized and very convenient for line art conversion.

Fig.5 shows a flowchart for the adaptive framegrabber during fingerprint enrollment process. This is the process when the image to produce the verification biocript is acquired.

The command start enrollment is issued by the CPU 8 only after the finger to be enrolled has been properly placed on the fingerprint image scanner 1. After it has been issued, the framegrabber is switched into grey scale mode of operation 16; the average vector is calculated for the first frame 17, proper offset and measurement range are selected for the video ADC 2 and downloaded to DAC1/DAC2 18. If the algorithm selected requires, the framegrabber is switched into line art mode of acquisition 19 and the

frame which will be used for enrollment purposes is acquired 20 and this ends the enrollment acquisition process 21. The framegrabber is disabled by the CPU 8.

While the above described embodiments of the invention are the preferred ones, it should be apparent to those skilled in the art that many other changes and modifications may be made, without departing from the invention in its broader aspects. Therefore, the intention of the claims is to cover such changes and modifications, falling within the true spirit and scope of the invention.

The embodiments of the invention, in which an exclusive property or privilege is claimed, are defined as follows:

CLAIMS

1. An adaptive (video) fingerprint image frame grabber, comprising a video analog to digital converter (ADC) to digitize the input (video) fingerprint image signal, a dual digital to analog converter to provide references for the measurement range and offset to the said analog to digital converter; a video synchronization decoding circuit, to extract frame and line synchronization signals from said input (video) fingerprint image signal; a memory to store digitized (video) fingerprint image data from the output of the said video analog to digital converter; a direct memory access controller to read digitized data from the output of said video analog to digital converter and save it into said memory; a programmable timer circuit to control the conversion cycle of said video analog to digital converter and to generate requests for said direct memory access controller cycles and a central processing unit (CPU) to control and synchronize the functioning of all said blocks, said central processing unit being interrupted by the frame synchronization pulses from said (video) fingerprint image synchronization decoding circuit, tests a preset value defining frames to skip count and skips the frame to be acquired if the test fails, otherwise the central processing unit enables interrupts caused by the line synchronization signals from said (video) fingerprint image synchronization decoding circuit; said interrupts interrupting said central processing unit each time a (video) fingerprint image line from current frame is to be acquired, the central processing unit then enables the said timer to provide timing signals to the said video analog to digital converter and respectively requests to the said direct memory access controller, and also enables the direct memory controller to read data from the output of the video analog to digital converter and save it into said memory; this process repeats itself until all lines have been acquired, the central processing unit then disables interrupts from said line synchronization signal; at the next interrupt caused by the said frame synchronization signal from the (video) fingerprint image synchronization circuit the central processing unit checks

for the said preset value defining frames to skip, and the process repeats until the adaptive frame grabber is disabled by the said central processing unit.

2. An adaptive (video) fingerprint image frame grabber as claimed in claim 1, wherein the preset value defining the number of frames to skip count is modified after each failed test.

3. An adaptive (video) fingerprint image frame grabber as claimed in claim 1, wherein the preset value defining the number of frames to skip is set to its initial value any time the frame is acquired.

4. An adaptive (video) fingerprint image frame grabber as claimed in claim 1, wherein when said central processing unit is interrupted by the line synchronization signal from said video synchronization circuit, said central processing unit tests first a preset value defining lines to skip from the beginning of the current frame and if the test fails skips the video current video line, otherwise the line is acquired.

5. An adaptive (video) fingerprint image frame grabber as claimed in claim 4, wherein said preset value defining lines to skip is modified each time its test fails.

6. An adaptive (video) fingerprint image frame grabber as claimed in claim 4, wherein said preset value defining lines to skip is set to its initial value any time its test is positive.

7. An adaptive (video) fingerprint image frame grabber as claimed in claim 4, wherein after a positive result from said test of said value defining lines to skip from the beginning of the frame, when the central processing unit is interrupted again by the line synchronization signal from said (video) fingerprint image synchronization circuit it tests a preset lines

to acquire value and if the test fails disables line synchronization signal interrupts from the said (video) fingerprint image synchronization decoding circuit, otherwise the current video line is acquired, digitized and saved into said memory.

8. An adaptive (video) fingerprint image frame grabber as claimed in claim 7, wherein said preset value defining lines to acquire is modified each time the result of said test is positive.

9. An adaptive (video) fingerprint image frame grabber as claimed in claim 7, wherein said preset value defining lines to acquire is set to its initial value each time the result of said test is negative.

10. An adaptive (video) fingerprint image frame grabber as claimed in claim 7, wherein before the start of acquisition of the current line the central processing unit checks a preset value for pixels to skip from the beginning of the line and skips corresponding number of pixels before enabling the acquisition, digitization and saving the line into memory.

11. An adaptive (video) fingerprint image frame grabber as in claim 10, wherein the central processing unit checks a preset value for pixels to acquire from the current line and enables the acquisition and saving into memory only a number of consecutive pixels corresponding to said value.

12. An adaptive (video) fingerprint image frame grabber as in claim 1, wherein, when said line synchronization signal interrupt from the video synchronization circuit is enabled by the central processing unit and said timer and direct memory access controller are also enabled by the central processing unit, said direct memory access controller is set for single word transfer from the digital output of the video analog to digital converter to the memory, its acquisition counter to the number of pixels to be acquired

from the current line, and said timer to be the request source for triggering direct memory controller single word transfers.

13. An adaptive (video) fingerprint image frame grabber comprising, a video analog to digital converter to digitize the input (video) fingerprint image data, a memory to save digitized (video) fingerprint image data from the video analog to digital converter, a central processing unit to control and synchronize the operation of the various functional blocks of the said (video) fingerprint image frame grabber, and a grey scale/ line art conversion buffer, wherein said grey scale/line art conversion buffer is placed between the digital outputs of the analog to digital converter and the memory and has two modes of operation controlled by the central processing unit; when in the first of the said two modes the grey scale/line art conversion buffer is fully transparent and the data from the digital outputs of the analog to digital converter is directly saved into memory; in the second mode the data from the digital outputs of the video analog to digital converter is compared first by means of a digital comparator to a preset digital threshold, and if said data is greater than said threshold all ones are assigned to all bits at the output of said grey scale/line art buffer and saved into memory, if on the other side said data is less than the threshold all zeros are assigned to the outputs of said buffer and saved into memory.

14. A (video) fingerprint image frame grabber as claimed in claim 13, wherein if said data from the outputs of the analog to digital converter is equal to said threshold all ones are assigned to the outputs of the said grey scale/line art conversion buffer and saved into memory.

15. A (video) fingerprint image frame grabber as claimed in claim 13, wherein if said data from the outputs of the analog to digital converter is equal to said threshold all zeros are assigned to the outputs of the said grey scale/line art conversion buffer and saved into memory.

16. A (video) fingerprint image frame grabber as claimed in claim 13, wherein said grey scale/line art conversion buffer is built on a two sets of inputs to one set of outputs multiplexer with data length equal to the bus width between said video analog to digital converter and said memory; first set of inputs connected directly to the digital data outputs of the video analog to digital converter, and the second set of inputs being connected to the output of an AND gate; one of the inputs of said AND gate being connected to the output of one OR gate, the remaining inputs correspondingly connected to the digital data outputs of the video analog to digital converter which must be in a state of one in order the digital data from the output of said analog to digital converter to be equal or greater than the selected threshold; on their side the inputs of the OR gate being connected to the digital data outputs of the analog to digital converter, and at least one of those outputs must be in a state of one in order the digital data from the output of the video analog to digital converter to be equal or greater than the selected threshold.

17. An adaptive (video) fingerprint image frame grabber comprising, a video analog to digital converter to digitize the input (video) fingerprint image data, a memory to save digitized (video) fingerprint image data from the video analog to digital converter, a central processing unit to control and synchronize the operation of the various functional blocks of the said (video) fingerprint image frame grabber, wherein at the start of the frame grabber operation an image window comprised by predefined number of pixels is extracted from acquired (video) fingerprint image frame and an average pixel vector is calculated equal to the sum of all pixels within said window divided by their number.

18. An adaptive (video) fingerprint image frame grabber as claimed in claim 17, wherein said average pixel vector is compared to a predetermined threshold; if the result of comparison is negativenext frame is acquired, the average pixel vector for said next frame is calculated until

a positive result of said comparison has been detected, said (video) fingerprint image frame grabber starts its regular operation for acquisition of (video) fingerprint image frames.

19. An adaptive (video) fingerprint image frame grabber as claimed in claim 17, wherein the calculated average pixel vector is used to select, depending on its value, the offset and measurement range of the video analog to digital converter.

20. An adaptive fingerprint image frame grabber as claimed in Claim 19, wherein the process of acquiring a fingerprint image, extracting said predefined number of pixels, calculating the average vector and depending on its value, selecting the values of the offset and measurement range of said video analog to digital converter, repeats until the value of the newly calculated average vector is within certain predetermined threshold windows.

FIG. 1

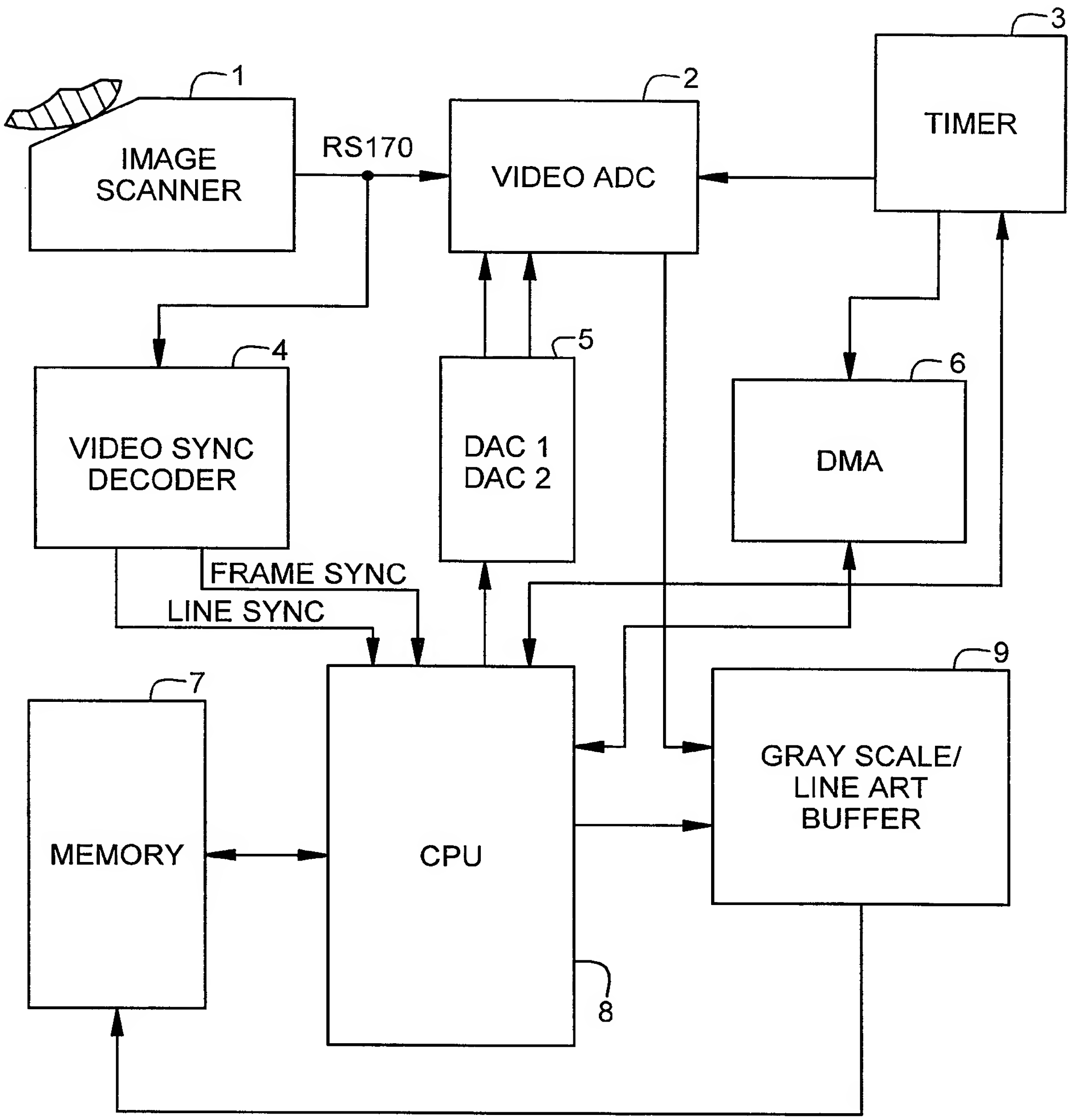
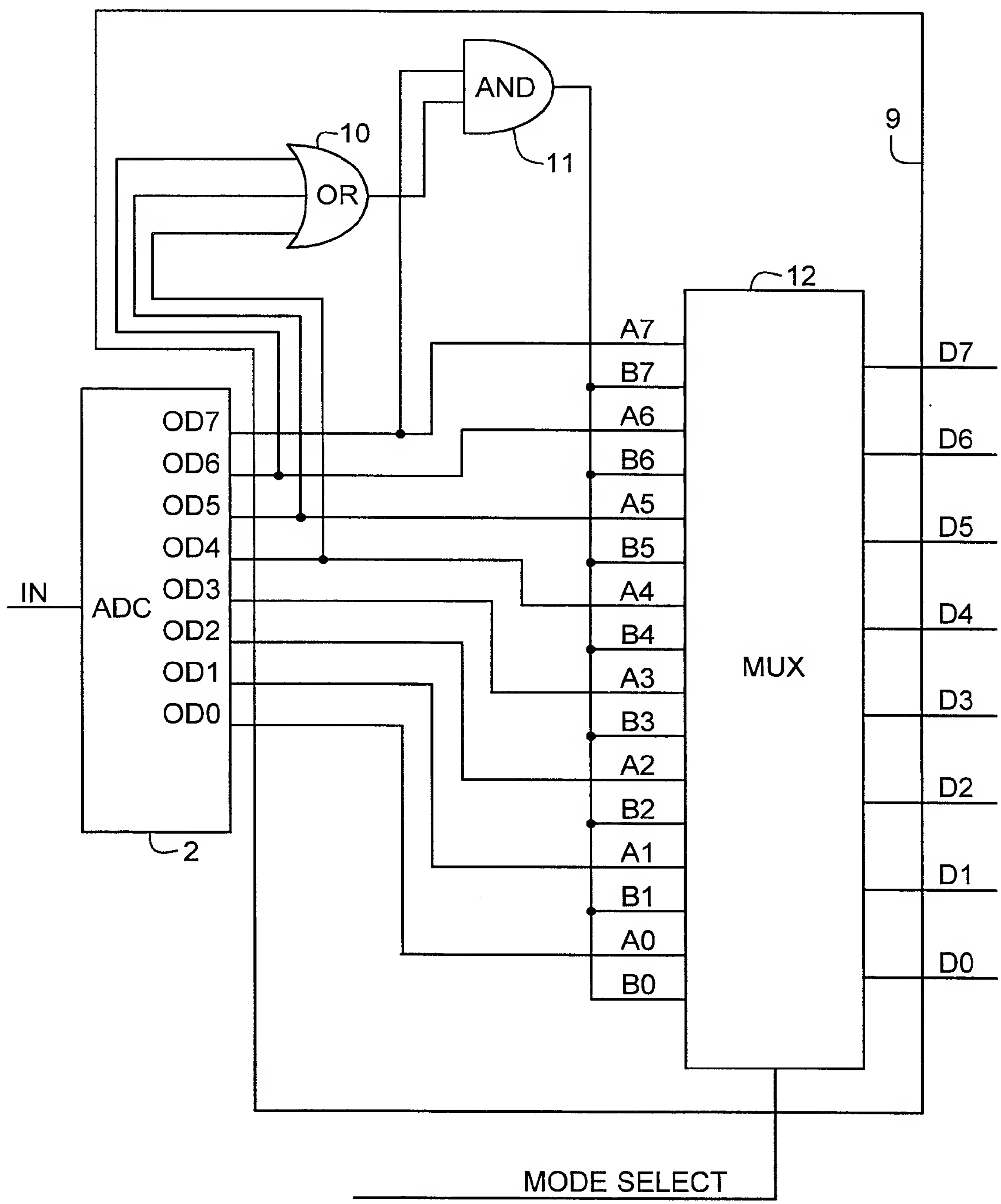


IMAGE SCANNER
1
RS170
VIDEO ADC
2
TIMER
3
VIDEO SYNC DECODER
4
DAC 1
DAC 2
5
DMA
6
FRAME SYNC
LINE SYNC
MEMORY
7
CPU
8
GRAY SCALE/ LINE ART BUFFER
9

FIG. 2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A0
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MUX
D7
D6
D5
D4
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OD1
OD0
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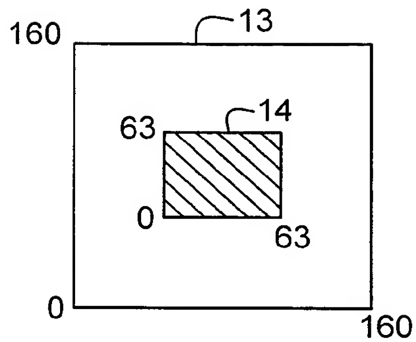
MODE SELECT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14
63
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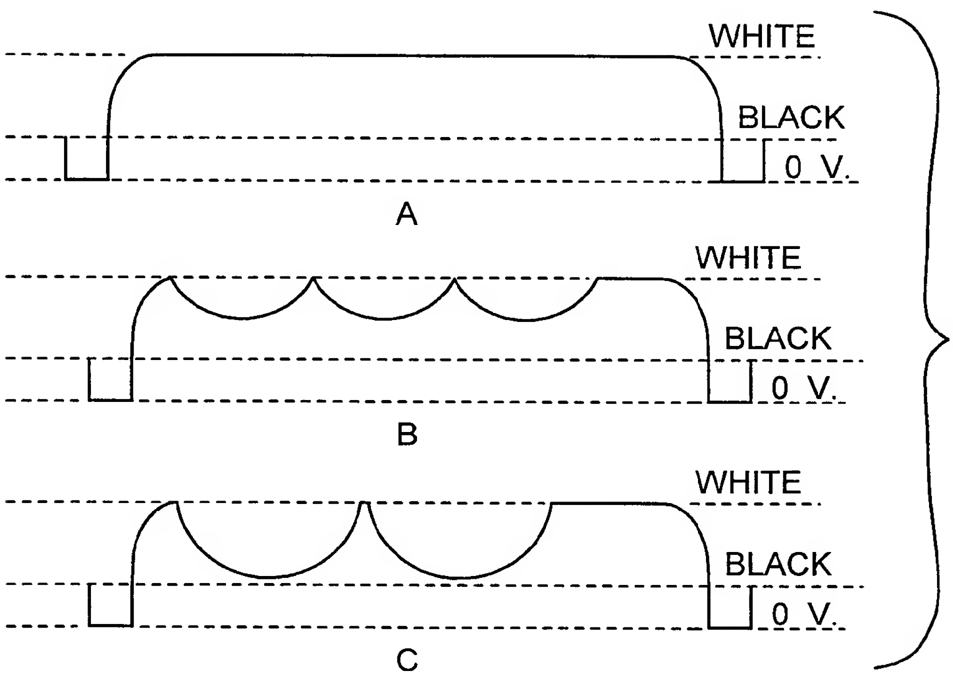
160

FIG. 3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WHITE
BLACK
0 V.
C

FIG. 4

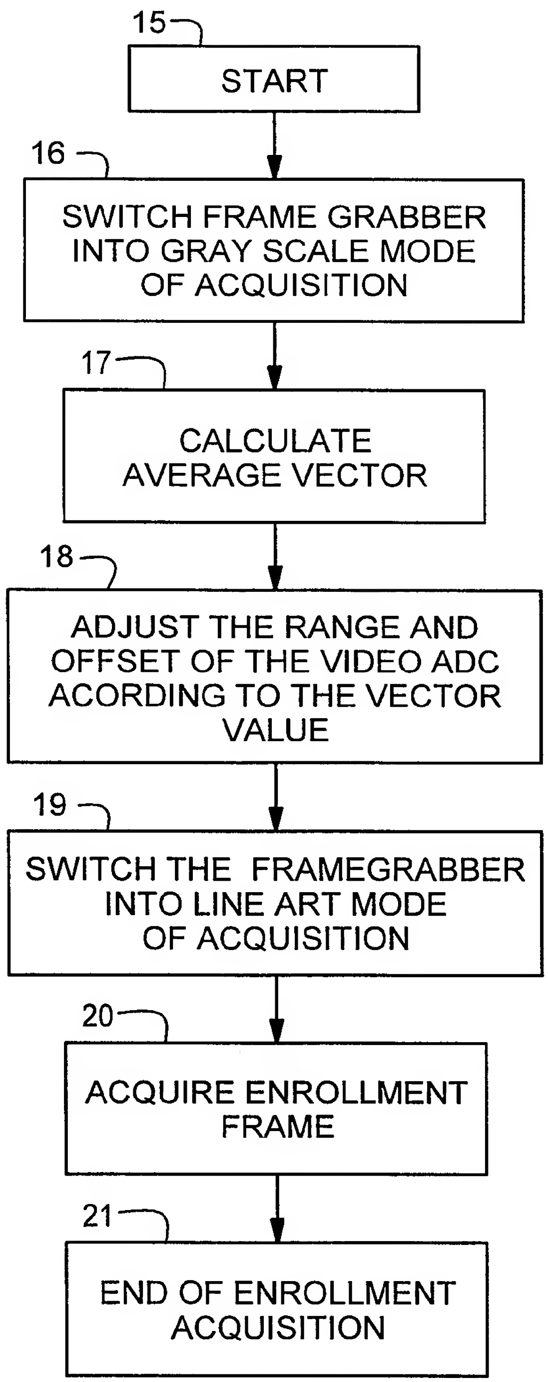
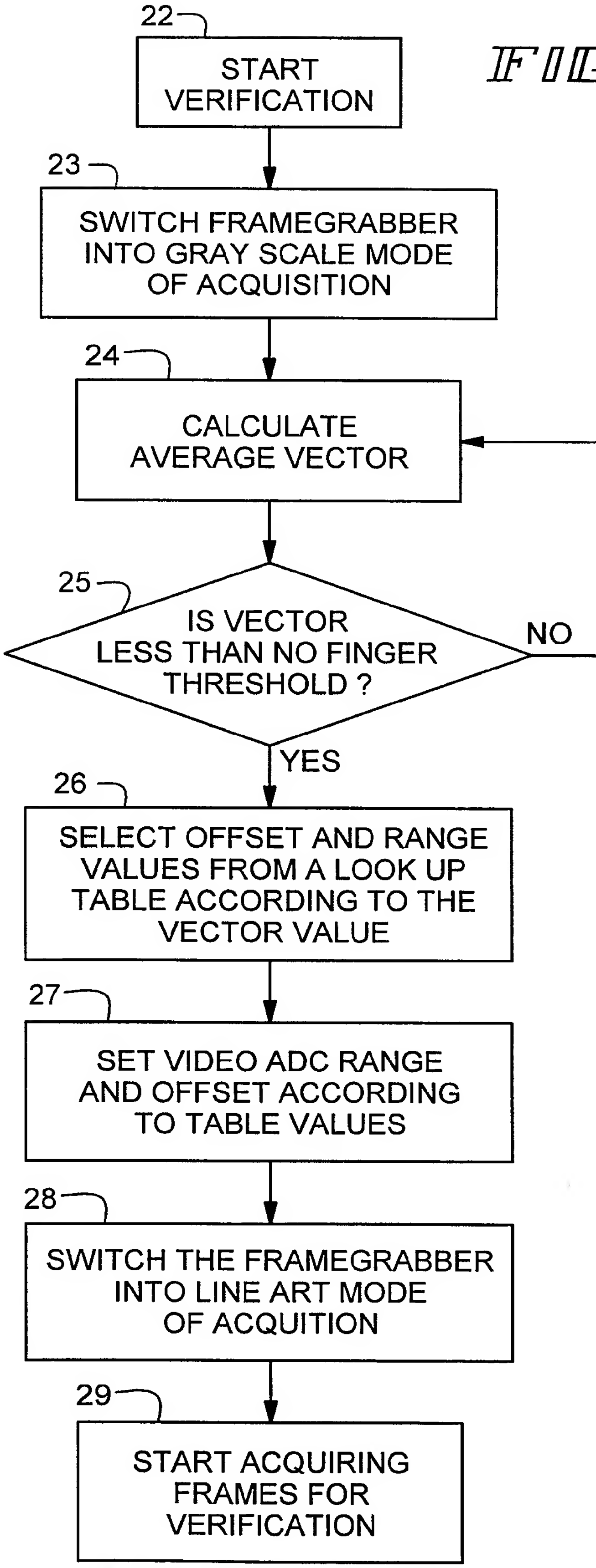

15
START
16
SWITCH FRAME GRABBER INTO GRAY SCALE MODE OF ACQUISITION
17
CALCULATE AVERAGE VECTOR
18
ADJUST THE RANGE AND OFFSET OF THE VIDEO ADC ACORDING TO THE VECTOR VALUE
19
SWITCH THE FRAMEGRABBER INTO LINE ART MODE OF ACQUISITION
20
ACQUIRE ENROLLMENT FRAME
21
END OF ENROLLMENT ACQUISITION

FIG. 5

FIG. 6


22
START VERIFICATION
23
SWITCH FRAMEGRABBER INTO GRAY SCALE MODE OF ACQUISITION
24
CALCULATE AVERAGE VECTOR
25
IS VECTOR LESS THAN NO FINGER THRESHOLD ?
NO
YES
26
SELECT OFFSET AND RANGE VALUES FROM A LOOK UP TABLE ACCORDING TO THE VECTOR VALUE
27
SET VIDEO ADC RANGE AND OFFSET ACCORDING TO TABLE VALUES
28
SWITCH THE FRAMEGRABBER INTO LINE ART MODE OF ACQUITION
29
START ACQUIRING FRAMES FOR VERIFICATION